A Dissertation on

RECONSTRUCTION OF TUBULAR BONE DEFECTS WITH NON VASCULARIZED FIBULAR GRAFT

Submitted to

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY

CHENNAI

In partial fulfillment of the regulations

For the Award of the Degree of

M.S. DEGREE BRANCH –II
ORTHOPAEDIC SURGERY

KILPAUK MEDICAL COLLEGE
CHENNAI

MARCH – 2007

CERTIFICATE

This is to certify that **Dr. R. VASANTHARAMAN** Post graduate student (2004- 2007) in the department of orthopaedics Govt. Kilpauk Medical College Chennai has done this dissertation on "**RECONSTRUCTION OF TUBULAR BONE DEFECTS WITH NON VASCULARIZED FIBULAR GRAFT"** under my guidance and supervision in partial fulfillment of the regulation laid down by the Tamil Nadu Dr. M.G.R Medical University, Chennai for MS (Orthopaedics) degree examination to be held on March 2007.

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DECLARATION

I, **Dr. R. VASANTHARAMAN,** solemnly declare that dissertation titled "**RECONSTRUCTION OF TUBULAR BONE DEFECTS WITH NON VASCULARIZED FIBULAR GRAFT"** is a bonafide work done by me at Kilpauk Medical College 2004 - 2007 under the guidance and supervision of my unit chief **Prof. A. SIVAKUMAR M.S (Ortho)., D.Ortho** Professor of Orthopaedic surgery.

This dissertation is submitted to Tamilnadu Dr. M.G.R Medical University, towards partial fulfillment of regulation for the award of M.S. Degree (Branch – II) in Orthopaedic surgery.

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ACKNOWLEDGEMENT

First and fore most I would like to thank **Prof. THIAGAVALLI KIRUBAKARAN M.D.,** Dean, Kilpauk Medical College for permitting me to use the resources and clinical material of this hospital.

I offer my sincere thanks to **Prof. SOMASEKAR M.D.,** Superintendent of Govt. Royapettah Hospital Chennai -14 for having permitted me to use the hospital material for this study.

I express my profound thanks to my esteemed professor and head of the department, **Prof. A. SIVAKUMAR** Govt. Royapettah Hospital for his valuable suggestions and help for this study

I thank **Prof. K. NAGAPPAN** and **Prof. K. SANKARALINGAM** for their encouragement and help for this study.

I thank **Dr. R. BALACHANDRAN** Assistant Professor Government Royapettah Hospital for encouraging and extending invaluable guidance as a guide to perform and complete this dissertation.

My sincere thanks to **Dr. P. ELANGOVAN, Dr. T. THOLKAPPIYAN, Dr. K. MOHAN KUMAR, Dr. V. THANIGAINATH and Dr. P. VEERANAN YADAV,** for encouragement throughout the period of this study.

Last but not the least my gratitude to the patients involved who was kind and cooperative.

CONTENT

INTRODUCTION

In our speciality of orthopaedics we come across many problems involving the bone and soft tissues like, fractures, infections, tumours etc., among these bony defects are a great challenge to us. These defects can be due to various causes such as post traumatic bone loss, post infective bone loss and defect resulting after excision of tumours. These defects have to be reconstructed to give better form and function to the patients. These defects can be either diaphyseal or osteoarticular. To reconstruct these defect is a surgical challenge. Surgical challenges may include primary articular defects, diaphyseal defects and salvage of other failed reconstructions. Many options are available that may be tailored to the individual's need.

Autograft, allograft, prosthetic replacement or allograft prosthetic composite are established methods for reconstructions. Among the autograft and allograft reconstructions it can be done either as vascularized or nonvascularized graft

Though the use of vascularized graft for reconstruction may provide rapid biological incorporation, growth potential in skeletally immature patients and the ability to thrive in compromised soft tissue environment. This procedure may not be possible in some of the centers for want of technical expertise however the long term follow up of nonvascularized fibular graft also gives good result. Hence we made an attempt to reconstruct the bony defects with nonvascularized fibular graft which is presented in this study.

AIM

To study the outcome of the nonvascularized fibular graft in reconstructing the tumour defects and gap nonunion of tubular bones.

To share our experience of these procedures done in our institution.

REVIEW OF LITERATURE

HISTORICAL REVIEW

History of Bone Grafting

Bone grafting is a very old surgical procedure. The first recorded bone implant was performed in 1668 .Over 200 years ago John Hunter demonstrated that separated fragments of bone could survive and grow **" Adhesion of detached splinters take place -----------not only in those which are attached to the soft parts but in those which are entirely loose".** In concluding that "these pieces must retain the living principle" he made the first accurate though quite unconscious forecast of the possibility of bone transplantation.

Nearly two centuries later, Hunter's words re-echoed in a monographic " bone looks so dead ; as if it were no more than a block of marble carved with delicate artistry to fit the structure around it and give them support and yet it is so very alive and forever busy shaping itself in adoption to constantly changing demands"[29] .

Von Meekran (1668)

Though he reported an attempt to repair a cranial defect in a Russian soldier with a dog's skull bone the failure of this heterogenous graft did not become, evident in as much as Von meekran was forced to remove the bone graft.

Ollier (1867)

The real interest in the bone graft followed the publication in 1867 of fundamental experimental work of ollier on bone grafting in rabbits, cats , dogs and birds .

First Successful Bone Transplantation[29]

In 1878 Macewen in Glasgow removed the entire diaphysis of the humerus of a 3 years old infant for persistent osteomyelitis . Fifteen months later he was asked to amputate the flail and useless limb. Instead he implanted a number of bone wedges excised during corrective osteotomies from six other patients. The procedure was done in three stages, two wedges being inserted at approximately two monthly intervals. **This was the first recorded example of successful homogenous bone grafting**. The transplanted bone regenerated and the rebuilt humerus measured 6 inches (15 cms) in length, more than two – third of it being from transplanted bone.

Lexer (1907)

The clinical application of bone allografting became prevalent in the first decade of the 20th century, after the experimental work of Ollier and Axhausen. **In 1907 Lexer was the first to perform allogeneic whole joint transplantation** and he had performed 25 cases by 1925.

Axhausen (1909–1911)

In 1909 Axhausen studied the osteogenic activity of periosteum and concluded that it was highest in autograft and lowest in heterografts.

Albee (1911)

Albee established the cortical bone grafting.

Macewan (1912)

Macewan presented paper on transplantation and replacement of a humerus in a patient and followed this by extensive experimental and clinical observation which was published in “Growth of bone” in 1912.

Phemister (1914)

In 1914 Phemister showed that osteogenesis in experimental animal occurs from periosteum also. It was Phemister who emphasized that the fate of transplanted bone depend upon perfect haemostasis, perfect asepsis and perfect co-aptation of parts.

Kappis (1915)

Kappis in 1915 employed full thickness rib with periosteum to cover the dural and cranial defects. After this many orthopaedicians have tried cortical bone grafts using fibula, tibia or ribs in filling the gap in the treatment after excision of the tumour of the dispensable part of long bone.

Gallie and Robertson (1918)

They proved that apart from periosteum, the preservation of blood supply plays main role in osteogenesis and the union of the graft with recipient bone and so undue stripping of periosteum should be avoided.

Inclan (1942)

In 1942 Inclan reported the storage of autogenous and allogenous bone and this report stimulated many similar clinical efforts at preservation, sterilization and delayed reimplantation.

T. L. Lawson et al (1952)

They removed a giant cell tumour from the lower end of the radius with a tumour clearance of 3 cms. The gap was filled by a free autogenous fibular graft taken from the ipsilateral side. The fibular head was made to articulate with the carpal bones. The proximal end of fibular graft and distal end of the recipient radius was fixed with two cortical screws, after making a step cut. Bony union between graft and recipient bone was present after 12 weeks and the wrist function was almost normal. The patient was a policeman.

Enneking and Hammock (1965)

They have reviewed cases and reported about the comparative study between vascularization of autogenous and homogenous bone transplants.

F. F. Parrish (1966)

In 1966, F.F Parrish used autogenous fibular graft in the treatment of bone tumours by resection.

Buchardt, Busbee and Enneking (1975)

These authors studied the repair of experimental autogenous grafts of cortical bone and have reported that the repair begin at 8 to 12 weeks during which bony union become evident.

Taylor and Daniel (1975)

The first free vascularized fibular graft was done by them in 1975 for tibial defect. They have taken the middle third of fibula with a main nutrient artery and a vein and anastamosed with the tibial vessels by microvascular surgery and the bony union was good in 12 weeks.

WF Enneking, JL Eady and H Burchardt (1980)

They analysed the result of using segmental cortical autogenous bone grafts to reconstruct defects created by resection of tumors in 40 patients. They formulated the principles of segmental cortical bone grafting. They are, rigid immobilization of the grafts in a stable extremity, the

graft must be protected through out the prolonged reparative phase until there is evidence of union, adequate stress must be transmitted to the graft during this period to stimulate the repair, enough grafts must be used to provide functional replacement in the major tubular bones.

Russell Moore et al (1983)

In 1983 Russel Moore et al used vascularized fibular graft for the gap more than 6 cms, producing good results.

M. Campanacci and P. Picci (1984)

They reported that fibular graft for giant cell tumour gives very good results and the wrist joint mobility is almost normal.

A. Jhow et al (1985)

In 1985 A. Jhow et al treated 18 cases of osteoclastoma lower end of radius by excising the tumour and the gap was filled with autogenous fibular graft. They had maximum follow up of average 7.1 years. But local recurrence in 5 patients, one died of pulmonary metastasis, nonunion in 5 patients and fracture of the graft in 3 patients.

SOURCES OF GRAFTS[28]

Autograft

The transplanted bone is derived from the same person receiving it. Autograft both cancellous and cortical, are usually implanted fresh and are often osteogenetic, whether by providing a source of osteoprogenitor cells or by being osteoinductive fresh autogenous bone is preferred since it is non antigenic and has superior osteogenic induction properties.

Isograft

Isograft is a graft exchanged between people with genetically identical characteristics from same zygote (e.g., identical human twins).

Allograft

An allograft is transplantation from one person to another of the same species, but with dissimilar genetic characteristics. When the graft is between member of different highly inbred lines, the allograft is termed “allogeneic”. Fresh allotransplant behave initially as fresh autogenous transplants, but ultimately induce an immune response which may reject the bone. Before implantation, allogenic bone must be processed to reduce its antigenicity, while preserving its osteogenic induction property and retaining its mechanical strength.

Various methods are used to process the bone before storage and most include freeze drying (lyophilization) which is generally believed to reduce the bone antigenicity so that the immune response in greatly delayed and reduced, permitting the induced osteogenesis in the recipient to proceed unhindered.

The disadvantage of lyophilization in the reduction of the mechanical strength of the implant and fatigue fracture and non union are frequent when allogeneic bone in used for massive segmental and osteoarticular implants. Such grafts must be stabilized both by internal devices and external supports for lengthy periods until union and repair are certain.

The processed and preserved allogeneic bone is not a substitute for autogenous bone.

Xenograft

A xenograft is transplantation from one person of one species to a person of another species. Different types of xenografts are.

- Bovine bone xenograft
- Type I collagen xenograft
- Composite xenografts

TYPES OF GRAFTS[18]

Multiple cancellous chips or strips

This is the most osteogenic and most widely used graft. The best source of cancellous bone graft is the ilium. It is the principle type of graft used for fractures, nonunions and for arthodesis of the spine.

Single onlay cortical bone graft

This was used most commonly before the development of good quality internal fixation and was employed for both osteogenesis and fixation in the treatment of nonunion. The tibia and split fibula can be used. The most common indication for this graft today is bone grafting and stabilizing the cervical spine.

Dual onlay cortical bone graft

Boyd developed the dual – onlay cortical bone graft technique in 1941 for the treatment of congenital pseudo-arthrosis of tibia. A version of this technique using allograft is useful for revision total joint arthoplasty to replace bone insufficiency.

Inlay bone graft

Albee popularized the inlay bone graft for the treatment of nonunion. Inlay grafts are created by a sliding technique, graft reversal technique, or as a strut graft. This technique is used for treatment of nonunion of the tibia, arthrodesis and epiphyseal arrest.

Sliding graft

A rectangular graft is cut and removed. It is simply flipped end for end and then impacted back into the slot. This technique is rarely used today. The disadvantages of the sliding graft is that graft fits loosely in the bed and it creates stress risers proximal and distal to the nonunion sites.

H–graft

The H-graft is a corticocancellous graft usually harvested from ilium specifically designed to achieve posterior fusion of the cervical spine.

Peg and dowel graft

Dowel grafts were developed for the grafting of nonunions in anatomic areas, such as scaphoid and femoral neck. In most instances, dowel grafts have been replaced by micro vascularized fibular grafts.

Peg grafts have also been used to bridge the tibia and fibula to produce proximal and distal tibio fibular synostosis.

Medullary graft

Medullary grafts are not indicated for the diaphysis of major long bones. Grafts in this location interfere with restoration of endosteal blood supply because they are in the central axis of the bone, they resorb rather than incorporate. The only possible use for a medullary graft is in metatarsals and metacarpals.

Osteoperiosteal graft

In osteoperiosteal grafts, the periosteum is harvested with chips of cortical bone. They are rarely used today.

Pedicle graft

Pedicle grafts may be local or moved from a remote site using microvascular surgical techniques. In local muscle-pedicle bone grafts, an attempt is made to preserve the viability of the graft by maintaining muscle and ligament attachments carrying blood supply to the bone or in the case of diaphyseal bone, by maintaining the nutrient artery. Advantage of high percentage of cell survival, rapid incorporation and increased active participation of the grafted cells in the healing process.

Whole Bone Transplant[27]

The fibula provides the most practical graft for bridging long defects in the diaphyseal portion of bones of the upper extremity. A fibular graft is stronger than a fill thickness tibial graft, and when soft tissue is scant, a wound that could not be closed over dual grafts may be closed over a fibular graft. Disability after removing a fibular graft is less than after removing a larger tibia graft. In children the fibula can be used to span a long gap in the tibia, usually by a two stage procedure.

Bone Graft Substitutes[9]

While autograft and allografts remain the most commonly used osteoinductive materials in reconstructive surgery, the limited availability and high cost of the bone graft, as well as concerns of transmitting infectious diseases have led to the development of several synthetic bone graft substitutes. The synthetics with clinical applications include hydroxyapatite (HA); tricalcium phosphate (TCP); calcium sulfate, bio active glass; injectable calcium phosphate polymer and composites of TCP, HA, and bovine collagen.

The products are biocompatible; they are also available as dense or porous implant or in granular form. Ceramics act as osteoconductors, where the product supports or acts as a scaffold, but does not generate new bone cells. In near future, synthetic growth factors coupled with calcium phosphate carriers are likely to provide osteoinductive as well as osteoconductive materials useful for skeletal reconstruction.

The ideal graft should have the following characters according to Red fern:

- Promotes bone healing
- Replaced by host bone
- Does not transmit disease
- Immunologically inert
- Provides mechanical support and maintains volume
- Easily handled.

ANATOMY OF FIBULA

Fibula is the slender lateral bone of the leg. It has a proximal head, a narrow neck, a long shaft and a distal lateral malleolus.

Head

Head is surmounted by a styloid process. It articulates with the lateral condyle of tibia. The arcuate ligament of knee joint is attached to it. The fibular collateral ligament and the biceps femoris are attached in front of the styloid process. The head of fibula resembles the distal radius and distal fibula.

Shaft

Shaft has three surfaces via anterior, lateral and posterior, corresponding to the extensor, peroneal and flexor compartments of the leg. Peroneus longus arises from the upper two third and peroneus brevis arise from the lower two third of the lateral surface of shaft. The common peroneal nerve enters peroneus longus at the neck of the bone, the nerve can be rolled against the bone here, where it may be damaged by a plaster cast or tight bandage. It also divides here into superficial and deep peroneal nerve. From the anterior surface extensor digitorum longus, extensor hallucis longus and peroneus tertius arises. From the posterior surface flexor hallucis longus, soleus and tibialis posterior arises.

Lateral Malleolus

The lateral malleolus articulates with talus. It gives attachment to posterior tibiofibular ligament, anterior tibiofibular ligament, anterior talofibular ligament, calcaneofibular ligament and posterior talofibular ligament. The groove on the posterior surface of the malleolus lodges the tendons of peroneus longus and peroneus brevis.

Vascular Supply

The blood supply is through peroneal artery. The peroneal artery gives off the nutrient artery for the fibula which enter the bone on it's posterior surface.

The proximal and distal ends receive metaphyseal vessels from the genicular and ankle arterial anastomoses respectively.

Applied Anatomy

1. The fibula does not take part in articulation of knee joint.

2. It takes no place in the transmission of body weight.

3. Distal fibula is important in maintaining the stability of ankle joint

Properties of Fibular Graft[13]

- It is a straight cortical bone
- A graft about 26 cm long can be harvested from an adult.
- Muscle, an articular surface proximally, and in a child a proximal physis are available.
- The dissection is superficial and straight forward
- Complications are minimal, especially if the peroneal nerve and tibial vessels are protected.
- Usually, overlying skin and nerve are not available.
- It is useful for long bone defects.

Indications for Fibular Graft

1. Reconstruction of large defects of long bone secondary to tumour resection
2. Reconstruction of large long bone defect secondary to sequestrectomy
3. Reconstruction of large bony defect secondary to trauma
4. Congenital pseudoarthrosis of tibia

5. Infection at the site of nonunion of the femur or tibia
6. Avascular necrosis of femoral head
7. Bridging of joints for arthrodesis
8. Mandibular reconstruction after tumour resection

Basic Principles[10]

The outcome of the graft is determined by specific properties of cortical and cancellous bone. Primary is *Osteogenesis:* the synthesis of new bone either by cells of graft or host origin. New bone of graft origin is produced by the surface cells of properly handled fresh cortical and cancellous grafts. This early bone formation accelerates incorporation during the first few weeks after surgery. Cancellous bone, with its large surface area covered with cells, has a greater potential for producing new bone of graft origin than does cortical bone.

New bone of host origin is produced through the process of *Osteoinduction.* This is a process whereby mesenchymal cells of the host are recruited to differentiate into osteoblasts. The recruitment and differentiation of these cells is probably modulated by low molecular weight polypeptides, such as the glycoprotein bone morphogenic protein (BMP). BMP is a hydrophobic, non species – specific protein that has been extracted from cortical bone of the diaphysis, from dentin and from various bone tumors. The activity of BMP does not require viable graft cells, and is present not only in fresh autografts, but also in modified allografts. Autoclaving destroys the activity of BMP.

The three – dimensional process of growth of capillaries, perivascular tissue, and osteoprogenitor cells of the host into the graft is termed *Osteoconduction*. The graft provides the “trellis” or framework for the ingrowth of this tissue.

In addition to these biologic functions, the graft may provide structural support until the recipient tissue can bear weight. Grafts of cortical bone most commonly provide structural integrity during remodeling. However, the incorporation of all grafts proceeds by creeping substitution, the gradual resorption of the grafts and replacement by new bone. Bone graft incorporation is characterized by five defined stages. It begins with inflammation, proceeds to osteogenesis and remodeling, and ends in a mechanically efficient structure.

PATHOPHYISOLOGY[28]

The autogenous cortical transplant in contrast to the cancellous transplant is revascularized at a slower rate. Blood vessels penetrate the volkmann's and haversian canal by the sixth day and complete vascularization occurs by 1 to 2 months. In addition at the surface of the cortical bone, vascular - cellular tufts termed "cutter heads" by osteoclastic resorption progressively burrow new tunnels into the bone.

In contrast to the cancellous bone repair, the process is initiated by osteoclastic resorption rather than by osteoblastic bone deposition. Resorptions begin at the outer regions of the transplant. In experimental cortical bone transplants observed in dogs, the rate at which the interior of the haversian canals is widened is significantly increased until the sixth week (excavation chambers), a phase correlated with loss of mechanical strength then the resorptive rate gradually declines to nearly normal level by the end of one year.

The active resorption process is at first preferentially directed towards peripherally located haversian system (osteons) reaching the interior by the fourth week. The interstitial lamellae remain relatively untouched. When appropriate cavity size is obtained resorption ceases and osteoblasts appears and rebuild concentric lamellae. The appositional phase occurs initially at 12 weeks after transplantation. **The repair is at first greater at transplant – host junctions and secondarily the repair advances towards the center of the transplant.**

The proportion of viable new bone to necrotic old bone increases from 2 weeks to 6 months after transplantation, but then the ratio appears to remains unchanged in transplants between 6 months and 2 years. Thus it can be seen that cancellous bone is completely repaired whereas cortical bone is only partially repaired and remains as an admixture of necrotic and viable bone.

Cellular Behaviour

Cell reaction is required to unite a bone graft with the recipient. Vessels can invade the osseous graft only when the shearing between the graft and host bone is eliminated. This is accomplished mainly by callus which glues the host tissue and graft firmly together.

Bone formation requires three factors:

1. Proper specialized cell
2. Proper nutrition
3. Proper stimulus

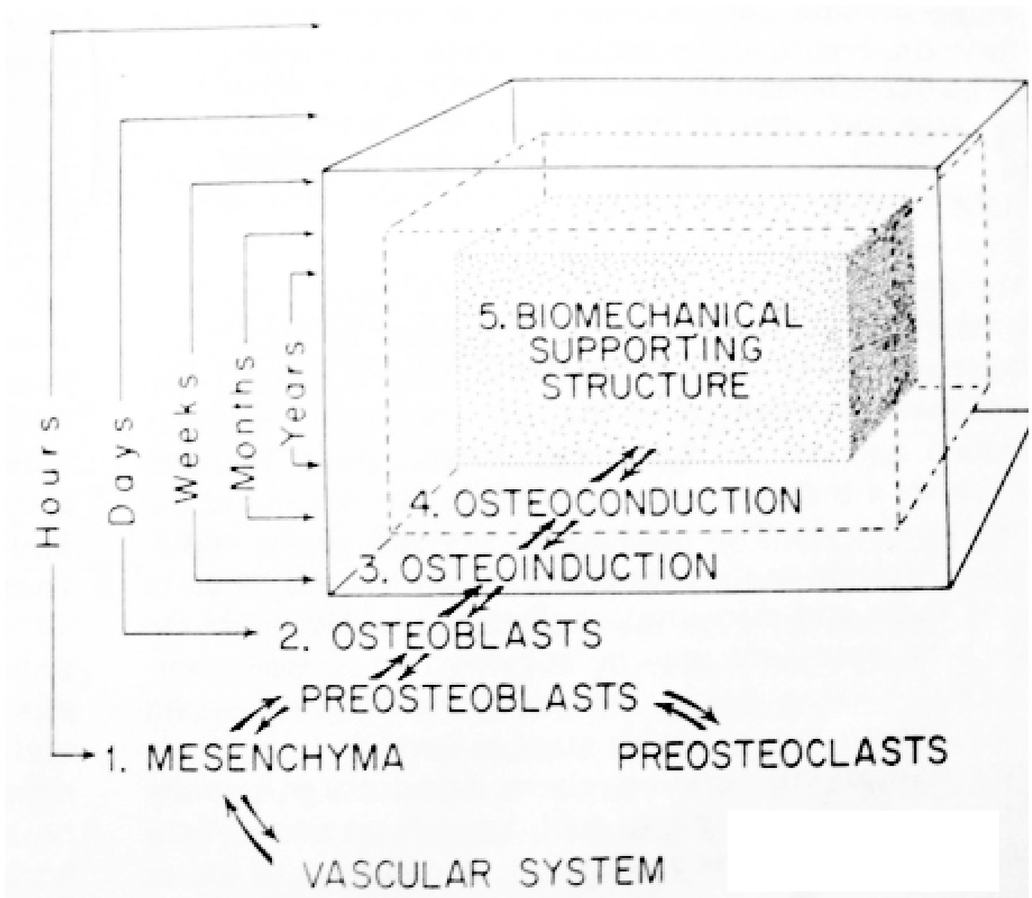
The proper cells arises from a mesenchymal stem cell which comes from perivascular cells, reticular cells of bone marrow, cells of trabecular surfaces and cells of cambium layer of periosteum. The specialization of cells in influenced by nutritional and electromechanical factors. When cells become compacted and the oxygen supply is adequate bone formation results.

OSTEOINDUCTION ROLE IN BONE GRAFT INCORPORATION (URIST)[28]

Incorporation

Defined as process of envelopment and interdigitation of donor necrotic bone with new bone deposited by recipient.

The incorporation of autogenous bone graft occurs in five stages:



The three dimensional relationships, time sequences and equilibra established in the five stages of incorporation of a bone graft. The end point is reached when the inert biomechanical structure of the donor tissue is completely encased in the remodeled lamellar bone deposits of the recipient. (Urist MR: instructional courses AM Acad. Orthop. Surg. 1976).

Stage I

Occurs within minutes to hours after surgery. This stage consists of inflammation, activation of migratory fibroblast like mesenchymal cells and proliferation of preosteoblasts and preosteoclasts in the recipient band.

Stage II and III

Begins one day to a week after inflammation and surgical injury subsides. This stage is characterized by cell osteoinductive interactions between protein macromolecules of donor bone matrix and cell surface receptor sites on the fibroblast like mesenchymal cells. In an autograft osteoinduction is activated immediately by secretions of osteoblasts. The induction response is regulated by a tissue- specific system consisting of a collagen-fiber entrapped bone morphogenetic polypeptide (BMP) and polypetidase (BMPase).

Stage IV

This stage consist of osteoconduction occuring over periods of months to years. It is characterized by ingrowth of sprouting capillaries and new bone. Promoted by compression between donor and host bone structure.

Stage V

This stage occurs over many years. The graft eventually becomes enmeshed in the structure of recipient bone.

Biophysical Behaviour

The repair process is a continuing phenomenon. In the process of incorporation of massive autogenous cortical bone transplant, the major amount of matrix resorption is intraosteonal, while the interstitial lamellar remain unchanged.

The mechanical strength of the transplant is related to the amount of resorption as related to bone mass and structural configuration. In man a two year period is required for completion of internal remodeling of the transplant. Union occurs between graft and host bone in 6 to 12 months. Restoration of mechanical strength requires about 2 years.

In experimental cortical bone transplants within the period from 6 weeks to 6 months post- transplantation, as porosity of the transplant is increased, the bone is approximately 40 % to 50 % weaker than normal. One to two years later the porosity is near normal and the mechanical strength and radiodensity are normal. Consequently segmented cortical transplants must be protected during the critical phase when resorption exceeds apposition and the transplant is susceptible to fatigue fracture and potential nonunion occurs.

Donor Site Morbidity[18]

Potential early complications include wound dehiscence, infection, seromas, hematoma, pain, injury to knee and ankle joint, injury to muscles, injury to peroneal nerve and vessel and compartment syndrome. Intermediate and long term complications include an ugly or painful scar, weakness of leg, lateral instability,proximal migration of lateral malleolus, valgus tilt[25], chronic pain, pseudoaneurysm and reflex sympathetic dystrophy.

Dropped Bone Graft[18]

All surgeons fear the day when a important autogenous bone graft just harvested from the patient is accidentally dropped to the floor of the operating room.

Chapman's approach to the dropped graft is as follows:

1. If a second graft can be harvested with no or minimal additional morbidity for the patient then discards the dropped graft and harvest a second graft.
2. If the dropped graft is essential and an additional harvest would subject the patient to additional morbidity then treat the graft as follow and use it.
3. Irrigate the graft using a pulsatile irrigator with two or more liters of saline depending on the size of the graft.
4. Then soak the graft in either antibiotic solution or in very dilute solution of povidone-iodine for atleast 10 minutes. Povidone has been shown to be cytotoxic to osteoblasts, so the solution should be weak and the surgeon must realize that this may result in death of any viable osteablasts in the grafts.

5. The graft can be inserted directly from the antibiotic solution or, if povidone solution was used, it should then again be irrigated to remove any residual iodophor.
6. Careful monitoring of the patient postoperatively and appropriate postoperative intravenous bacteriocidal antibiotic are appropriate.

ADVANTAGES

- Ready available and technically simple
- Upper fibula is a dispensable bone
- No instability at the donor site
- Any length of bone can be taken except the lower third of fibula.
- Head of fibula almost resembles the lower end of radius hence giving best fit for distal radius and distal fibular reconstructions.
- Being a cortical bone, it gives mechanical and biological strength to the recipient bone.
- No risk of disease transmission as it is autogenic

DISADVANTAGES

- Slow graft incorporation
- Prolonged immobilization and protection is needed

- Fracture of the graft
- Necrosis of the graft and failure is slightly higher than the vascularized fibular graft.

Materials and Methods

MATERIALS

This was a retrospective study conducted at Government Royapettah Hospital between 2002 and 2006. In this period of four years we analysed the hospital records to find out the cases treated by fibular strut grafts. Among the 30 cases of various tumorous conditions that were treated by us we identified 15 cases where the defects were treated by fibular reconstruction.

The list of trauma cases were also analysed and we identified 5 cases with significant bone defects for which reconstruction was done with fibular graft. So tumorous condition and trauma cases put together we had 20 cases for this study.

List of 20 cases as follows

Diagnosis	No of cases		
	Male	**Female**	**Total**
Fibrous dysplasia	2	-	2
Aneurysmal bone cyst	-	2	2
Osteoclastoma	6	3	9
Chondromyxoid fibroma	1	-	1
Chondro sarcoma	1	-	1
Non union humerus	2	-	2
Non union tibia	1	-	1
Non union supra condylar femur	1	1	2
	14	6	20

Thus in our study upper limb was involved in 11 cases and in rest of 9 cases lower limb was involved. Humerus and distal radius put together constitute more than 50% of the cases.

The age of the patients ranged from 8 years to 52 years. The average age being 28 years. Out of 20 cases 6 cases were female rest 14 are males.

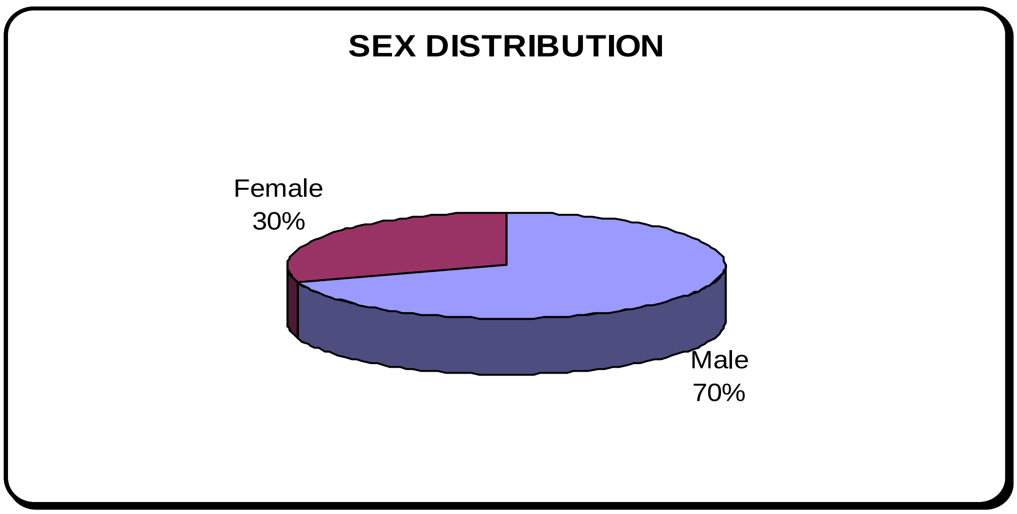
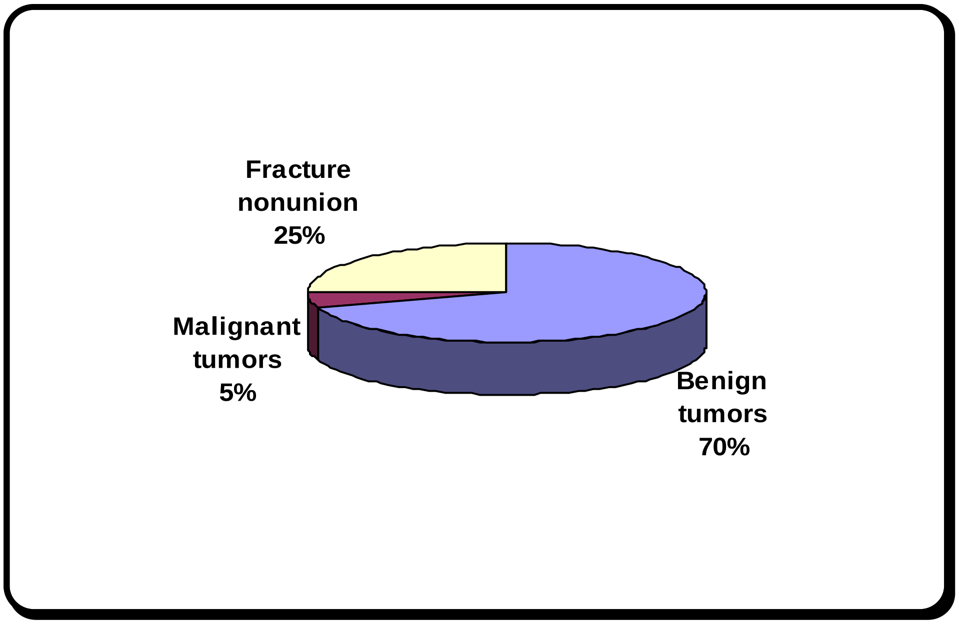


TABLE 1

AGE DISTRIBUTION

Age Group (Years)	Male	Female	Total
0 – 10	1	1	2
10 – 20	4	1	5
20 - 30	4	1	5
30 - 40	3	2	5
40 - 50	2	0	2
50 – Above	0	1	1

OUR STUDY GROUP



As indicated by the pie chart the majority of the study group consisted of benign tumors and the benign tumors which required anything less than wide resection were excluded since that defect were not significant enough to be treated by fibular strut graft. The list of the benign tumors of our study group is given below.

LIST OF BENIGN TUMORS

	Male	Female	Total
Fibrous dysplasia	2	0	2
Aneurysmal bone cyst	0	2	2
Giant Cell Tumour	6	3	9
Chondromyxoid fibroma	1	0	1

Among the benign tumours giant cell tumour was the most commonly encountered one comprising 64%. As described in the literatures the distal radius is the most favoured site for giant cell tumour in our study. These cases were either aggressive type or late presentation necessitating wide resection. So also in case of Aneurysmal bone cyst, we encountered presentation with extensive involvement of the humerus not amenable for curettage or bone grafting. In the cases of fibrous dysplasia one presented with pathological fracture and the other case was a recurrence after an initial treatment of curettage and bone grafting.

The one malignant tumour we had, was low grade chondro-sarcoma of the tibial cortex which required wide resection. The remaining cases with bone defects were due to complications of comminuted fractures, resulting in gap non union and the cases of infected nonunion were excluded.

The locations of the defects that were reconstructed are shown below.

Site of reconstruction	**No. of patients**
Humerus	6
Distal part of Radius	6
Distal part of Femur	4
Proximal part of tibia	1
Distal part of tibia	1
Shaft of tibia	1
Meta tarsal	1

METHODS

Preoperative evaluation done for the tumour cases were complete haemogram, serum studies, radiography of appropriate parts, skeletal survey. Serum studies consisted of serum calcium, serum phosphorus and serum alkaline phosphate. CT and MRI of the lesion and near by joint were also done. It is with these investigations (MRI & CT) we identified the exact extent of the lesion, cortical / articular breach etc. Based on this wide resection was planned along with reconstructions.

However the histopathological (biopsy) study of some of the cases helped us to plan for wide resection (aggressive giant cell tumour). HPE was done as excisional biopsy for some of the benign tumour of the study. The patients were selected only if preoperative imaging had shown that a satisfactory surgical margin could be achieved. Patients with expected defects larger than 10cm were excluded from the study because vascularized fibular graft in a better option in such condition[27].

Fracture nonunion cases were evaluated preoperatively by means of complete haemogram, total count, differential count, erythrocyte sedimentation rate and radiography of the appropriate part. Patient with infected nonunion were excluded. The other investigation to assess the general condition of the patients regarding fitness of the surgery were also done. All patients were given intravenous antibiotics before surgery.

As for as approaches are concerned

1. Volar approach for wrist

2. Posterior approach for humerus

Lateral approach for tibia, femur and dorsal approach for metatarsal were used.

Surgical Technique

In order to decrease the time of surgery and to avoid contamination we had two operation teams one for tumour resection and another for graft harvesting.

Tumour resection

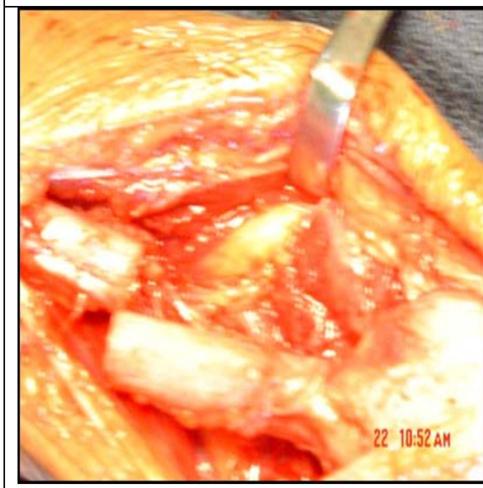
Under anaesthesia without using tourniquet incision was made such that it includes the biopsy scar. The tumour was resected en-block with wide margin. The margin of clearance ranged from 2.5 to 5 cm. At most care was taken to avoid contamination to near by tissues. The resected segment was measured, to plan the length of the graft to be harvested.

Harvesting the graft[27]

Through posterolateral approach (Henry approach) skin incised depending up on the requirement. If proximal third of fibula is to be resected, the common peroneal nerve along the posteromedial aspect of the biceps tendon in the proximal part of the wound is identified and protected. The fascial plane between soleus muscle and peroneus longus muscle is located and the dissection is deepen to reach the fibula. Subperiosteal stripping was started distally and progressed proximally in order to protect the anterior tibial vessel that passes between the neck of fibula and the tibia. The fibula was resected according to the length of the bony defect. In some cases nutrient artery entering the posterior surface of fibula required ligation. After resection was completed, the bicep femoris tendon and the fibular collateral ligament were sutured to the adjacent soft tissues.

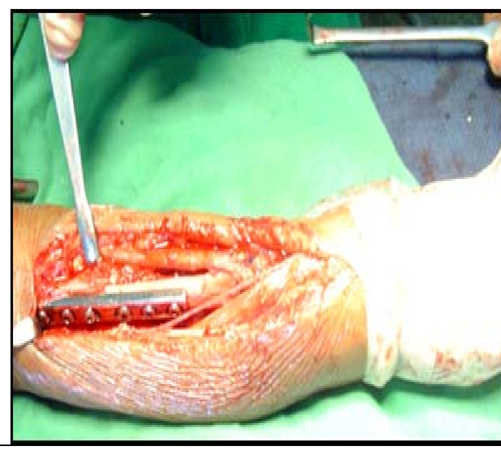
As per the above technique the proximal fibula was harvested in 6 cases (for distal radius reconstruction) and shaft of the fibula was harvested in rest of the cases. After bony reconstruction, the soft tissue reconstruction was done.

Tumour Resection



Resected Tumour

Reconstruction



Fixation of the graft

In order to enhance union rigid immobilisation was sought with internal fixations. The graft was fixed to the host bone either with a plate and screws, or with lag screws if a step cut osteotomy was performed or with Kirschner wires.

Post Operative Protocol

All our patients received five days of post operative intravenous antibiotics. Sutures were removed 10-12 days after surgery and sent home with plaster cast. This was maintained usually for six to eight weeks. Then the extremities were taken out of cast and appropriate brace or splints were given with advice for passive movements only. In case of lower limb partial weight bearing was allowed after 12 weeks and in case of upper limb gentle mobilisation was started after 6 weeks.

All our patients were reviewed clinically and radiologically at regular interval of one month upto 6 months. After 6 months they were followed up at 2 months interval till union or incorporation.

ANALYSIS

We analysed our patients in terms of graft incorporation, oncological evaluation and functional outcome.

Graft Incorporation[5]

Criteria for incorporation was absence of radiolucency at host donor junction and presence of smooth external continuity of cortical bone on all sides at the junction.

Non union was arbitrarily defined as an absence of union at one year after the operation.

Oncological Evaluation[20]

The oncological parameters that were studied includes survival of the patient, local recurrence and metastasis

Functional Out come

The patients were evaluated functionally as described by **Mankin et al scoring system[20].**

Excellent

Means that the patient had no evidence of disease, was pain free and had essentially normal function with No limitations (excepts with regard to high performance sports activity).

Good

Means that the patient has some degree of impairment of function that did not necessitate bracing or use of supports (such as crutches or a cane) or interfere with the patients occupations or life style (except with regard to sports activities).

Fair

Means that a brace or support was needed for walking or prehension and that the patient had sufficient pain to impair function.

Failed

Means graft removed or limb amputated. Death as a result of a local recurrence was also an indication of failure.

The follow up period ranged from 11 months to 4 years. All our patients were analysed in terms of graft incorporation, oncological evaluation and functional evaluation.

Graft incorporation was assessed radiographically. In our study the graft united in 16 out of 20 patients between 4 to 12 months period. Average time of graft incorporation was 7.2 months. 4 months in children, 6 months in case of wrist and 8 to 12 months in case of other bones. In the remaining four cases the graft did not incorporate due to various reasons that is discussed in later part of this text giving poor result.

Oncological evaluation was done only for the tumours conditions, out of 15 tumour cases 14 remained free from disease till date and one patient was operated for recurrences of giant cell tumour .

RESULTS

Results were based on functional outcome which was analysed according to **Mankin et al criteria.**

Following were our results:

Excellent	-	10 cases
Good	-	3 cases
Fair	-	3 cases
Failed	-	4 cases

Complications

COMPLICATIONS

The following were the complications in our study

1. Stitch abscess – one case
2. Early post operative infection – one case
3. Persistent Infection – three cases
4 Recurrence of tumour – one case
5. Donor site complications – two cases

In our study we had few post operative complications. One case of stitch abscess and one case of early post operative infection treated appropriately.

One case of recurrence was encountered with distal radius giant cell tumour for which excision and centralization of the ulna was done.

We had three cases of persistent infection which resulted in necrosis of the graft and failure.

Regarding donor site morbidity one patient had transient peroneal nerve palsy which recovered on physiotherapy and splinting. Another patient had permanent peroneal nerve palsy planned for tendon transfer.

Graft incorporated in 4 months.

Mankin et al score – Excellent

CASE -I

Pre operative X-ray

Post operative (immediate)

Followup

Functional Outcome

CASE - II

14 years old kameswaran had fibrous dysplasia but presented with pathological fracture of right humerus at first instances planned for resection and reconstruction. Tumour measuring 3.5 cm along with 2.5 cm of clearance was resected and reconstructed with 8.5 cm of allograft from mother fixed with plates & screws.

Graft incorporated in 4 months

Mankin et al score – excellent

CASE –II

Pre operative X- ray | **Post operative (immediate)** | **After implant exit**

Functional Outcome

CASE – III

26 yrs old kottamma presented with Giant cell tumour of the left distal radius. 10 cm autograft was fixed to the host bone with plate and screws. This patient developed transient peroneal nerve palsy which recovered with physiotheraphy and splint.

At six months patient developed recurrence of tumour / infection for which removal of graft and centralization of ulna was done.

Mankin et al score – failure

CASE -III

Pre operative X- ray

Post of X-ray (immediate)

Complications

CASE - IV

Mrs. Aysha 52 yrs presented with giant cell tumour of right distal radius. The histopathological specimen of the patient revealed aggressive type of tumour, planned for resection. 10 cm of the distal radius was resected with clearance and was reconstructed with same size autograft. Post operatively the patient had stitch abscess which was treated appropriately.

Graft incorporated in 6 months

Mankin et al score – excellent

CASE -IV

Pre operative X- ray

Post operative (immediate)

Followup

Functional Outcome

CASE – V

21 yr old Mr. Prabhu presented with recurrent chondromyxoid fibroma of shaft of 1st metatarsal right foot following curettage and bone substitute done 1½ yrs back. This patient had foreign body reaction with probable recurrence. 1st metatarsal along with medial cuneiform was removed and the defect was reconstructed with 9.5 cm autograft stabilized with two kirschner wires.

Graft incorporated in 8 months.

Mankin et al score – Excellent

CASE –V

Pre operative X- ray

Clinical Picture

Post operative (immediate)

Followup

CASE –VI

Mr. Mani 40 year old male presented with bony defect of right tibia following trauma who had external fixation and plastic procedure done for grade III B compound fracture of both bone right leg elsewhere. 6 cm bony defect was reconstructed with same size fibular strut graft fixed with plate and screws. There was persistent infection leading on to wound dehiscence and sequestration of the graft. Treated with graft removal and ilizarov fixator.

Mankin et al score – failure

CASE –VI

Pre operative X- ray

With External Fixator

With Fibular Graft

CASE – VII

50 yr old Mr. Thangamuthu presented with giant cell tumour of lateral femoral condyle for which curettage and fibular strut graft was planned. The tumour was thoroughly curetted and filled with bone cement. The lateral pillar was reconstructed with fibular strut graft measuring about 8 cm.

Graft incorporated in 8 months.

Mankin et al score – Good

CASE - VII

Pre operative X- ray

Post operative (immediate)

Followup X-ray

Functional Outcome

DISCUSSION

The goal of treatment is to cure the patient while preserving as much function, anatomical alignment and quality of life as possible. Thus every effort should be made to totally eradicate the primary lesion during the initial surgical treatment itself. Thus enbloc resection is strongly recommended for aggressive/ recurrent benign lesions and for some of the low grade malignant tumour. Reconstruction is necessary after adequate resection of tumor to preserve the function and alignment. Many reconstructive options are available after resection.

Autograft, allograft, prosthetic replacement or allograft prosthetic composite are established methods for reconstructions. Although use of allograft has shown encouraging results, there are many associated problems. Selection of suitable donors, the method of obtaining and preserving the graft, and the technique of allograft reconstruction deserves particular attention. The surgeon must consider the risks of infection, graft rejection, delayed healing and functions of the concern part. Custom-made prosthetic devices have been used with early success, but problems with late loosening and metal fatigue have not been solved.

Among the autograft and allograft reconstructions, it can either be with nonvascularized or vascularized graft. Vascularized fibular autograft is technically more demanding with use of microsurgical techniques. Nonvascularised fibular graft incorporation as an autograft is more rapid and predictable than an allograft[4]. Moreover, it is easily accessible without significant donor site morbidity[3,13]. It is also a biological solution and most of orthopaedic surgeons can perform this surgery in an average set up. They are associated with relatively low rate of complication and they survive for a longer duration, where as metal implants are difficult to design and have shorter life span.

In our study nonvascularized fibular graft was used for reconstructing defects in humerus, distal radius, distal femur, metatarsal shaft and proximal tibia that araised due to resection of tumorous conditions and complication of trauma. We had 14 cases of benign and one case of malignant tumour which were resected and reconstructed with non vascularized fibular strut graft.

Out of 15 tumour cases, 6 cases were giant cell tumours involving the distal radius which was reconstructed with the proximal fibula giving excellent results because of there structural similarity except one case of recurrence.

In another 3 cases the defects were near large joints (distal femur and proximal tibia). In these cases the fibular graft were augmented either with bone cement or bone grafting. Even though we could clear the disease and achieve anatomical alignment there were some impairment of joint movements. Thus functional outcome was good to fair in cases of large joint involvement.

In case of distal tibia giant cell tumour after resection the reconstruction was done by arthrodesis of tibia and calcaneum with fibular graft augmented with Kuntscher nail. Here the functional outcome was fair because the patient developed calcaneus deformity.

In two cases of pediatric group the tumours were involving the shaft of humerus for which fibula was used as intercalary graft, taken from their mother. Inspite of it being an allograft these cases showed early incorporation of the graft resulting in excellent functional outcome. This was probably due to good osteogenic potential and remodeling capacity.

We could eliminate the tumours in 14 out of 15 cases (93.3%); one case of giant cell tumour recurred. This case was further treated by excision and centralization of ulna.

As for as trauma group are concerned we had five cases out of which 3 cases resulted in failure. Out of these 3 cases, 2 cases were compound injuries to start with and had initial treatment else where in the form of external fixator. Both there cases presented to us with compromised soft tissue which could not withstand our extensive procedure of reconstruction resulting in would dehiscence and infection. The graft sequestrated and subsequently managed by the orthofix and ilizarov fixators.

In the third case of failure the graft did not incorporate probably due to inadequate fixation even after 1 ½ years, which was subsequently managed by bone grafting and replate osteosynthesis.

In our study 65 percent (13 of 20) had stable, painless extremity and resumed active use of the involved extremity without protective device after 1 year. The 7 patients who did not, were the 3 cases with fair results and 4 cases of failure. The fair result in 3 patients were because of painful extremity and they required assistive devices; two patients with distal femur reconstruction had knee stiffness and flexion deformity. The other patient with distal tibia reconstruction had calcaneus deformity.

The four patients with failure were due to infection, non union and recurrence.

In summary considering the problems for which the reconstruction were done 13 out of 20 patients (10 excellent and 3 good) had satisfactory results.

CONCLUSION

- The bony defects arising out of wide resection of the benign tumour can be successfully reconstructed with fibular graft – giving good functional outcome.
- Post traumatic bony defects with late presentation and cases with compromised soft tissues did not give satisfactory results with this procedure.
- However these bony defects can be successfully managed with fibular reconstruction when they present early to the surgeon.
- Our overall experience with nonvascularized fibular graft for reconstructing bony defects are encouraging, however we are aware this is a short term study and would require further evaluation and more inputs.

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PROFORMA

Name:	Age/ Sex	IP No.
Hospital:	Unit:	Ward:
Address:		
Phone No:	Date of Admission:	
	Date of Surgery:	

Diagnosis:

Procedure:

Clinical Features:

Physical Examination:

Investigations

Serum Study

Routine Blood Investigation

X-ray

Skeletal Survey

CT scan/ MRI

Biopsy

Treatment

Type of Defect

Type of Graft Used

Length of Graft

Mode of Fixation

Antibiotic protocol

Followup

Complications

Graft Incorporation

Oncological Evaluation

Functional Outcome

MASTER CHART

S. No.	Name	Age (Yrs.) & Sex	Diagnosis	Site	Type of Defect	Graft length (cms)	Mode of fixation	Complications			Deformity or Disability	Need of Brace or support	Time of union (months)	Durations of followup (months)	Graft incorporation	Functional Outome	Remarks
								Donor site	Recipient site Immediate	Recipient site Late							
1	Karthik	8, M	Recurrent Fibrous dysplasia	(Lt) Humerus	Diaphysis	8	Screws	-	-	-	-	-	4	20	Consolidated	Excellent	-
2	Kameswaran	14,M	Fibrous dysplasiawith pathological fracture	Rt. Humerus	Diaphysis	8.5	Plates & Screws	-	-	-	-	-	4	29	Consolidated	Excellent	Implant Exit done
3	Mohan	34, M	Low grade chondrosarco ma	Rt. Tibia	Osteo articular	9	Screws	-	-	-	Limitation of Joint Movement	-	8	18	Consolidated	Good	-
4	Kottamma	26,F	Giant cell tumour	(Lt) Distal radius	Osteo articular	10	Plate, screws and 'K' wires	Transient peroneal nerve palsy	-	Recurrence	Failure	Failure	failure	17	Graft removed	Failed	Centralization of ulna done
5	Ayesha	52, F	Giant cell tumour	(Rt) Distal radius	Osteo articular	10	Plate, Screws & K wires	-	-	-	-	-	6	12	Consolidated	Excellent	-
6	Rajabunisha	36,F	Giant cell tumor	Distal radius (Lt)	Osteo articular	8	Plate, Screws & K wires	Peroneal nerve palsy		-	-	-	5	42	Consolidated	Excellent	Planned for Tendon Transfer
7	Sekar	25, M	Giant cell tumor	Distal radius (Lt)	Osteo articular	7.5	Plate, Screws & K wires	-	-	-	-	-	7	36	Consolidated	Excellent	-
8	Prabhu	19, M	Recurrent chondromyxoid fibroma	1st Metatarsal (Rt) foot	Osteo articular	9.5	K wires	-	Infection	-	-	-	8	11	Consolidated	Excellent	-
9	Thangamuthu	50, M	Giant cell tumor	Lateral femoral condyla (Lt)	Osteo articular	8	-	-	-	Pain	Fixed flexion deformity	-	8	12	Consolidated	Good	-
10	Rajendra Prasad	24, M	Giiant cell tumor	Distal radius (Rt)	Osteo articular	7	Plate, screws & K wires	-	-	-	-	-	6	12	Consolidated	Excellent	-

S. No.	Name	Age (Yrs.) & Sex	Diagnosis	Site	Type of Defect	Graft length (cms)	Mode of fixation	Complications: Donor site	Complications: Recipient site – Immediate	Complications: Recipient site – Late	Deformity or Disability	Need of Brace or support	Time of union (months)	Durations of followup (months)	Graft incorporation	Functional Outome	Remarks
11	Ragu	22, M	Giant cell tumour	Distal femur (Rt.)	Osteo articular	6.5	-	-	Infection	-	Only jog of movement	Brace	11	30	Consolidated	Fair	-
12	Mani	40, M	Fracture non-union	Tibia (Rt)	Diaphysis	6	Plate & Screws	-	-	Infection	Shortening +	Brace	failure	13	Failure necrosis of graft	Failed	ilizarov was applied
13	Selvam	19, M	Fracture nonunion	Humerus (Rt)	Diaphysis	5	Plate & Screws	-	-	Implant failure, non union	Shortening +	Brace	failure	42	Necrosis of graft	Failed	Cortical onlay graft applied with plate & screws
14	Shahul Hamad	32, M	Fracture non union	Humerus (Rt)	Diaphysis	5	Plate & Screws	-	Infection	Non union	Shortening +	Brace	failure	14	Necrosis of graft	Failed	Treated with implant exit and ortho fix external fixator
15	Gobi	20, M	Fracture non union	Supra condylar femur (Lt)	Osteo articular	8	Plate & Screws	-	Infection	-	Fixed flexion deformity and limitation of movement	-	12	18	Consolidated	Good	-
16	Radika	37, F	Fracture non union	Supra condylar femur (Lt)	Osteo articular	8	Plate & Screws	-	-	-	Shortening + knee stiffness +	-	12	15	Consolidated	Fair	-
17	Pandiyan	50, M	Giant cell tumour	(Rt) Distal radius	Osteo articular	8	Plate & Screws	-	-	-	-	-	6	14	Consolidated	Excellent	-
18	Kamaraj	27, M	Giant cell tumour	Distal tibia (Rt)	Osteo articular	9	k' nail	-	-	-	Loss of ankle movement	Crutch	8	16	Consolidated	Fair	-
19	Kumudha	15, F	Aneurysmal bone cyst	Humerus (Lt)	Diaphysis	6	Plate & Screws	-	-	-	-	-	5	15	Consolidated	Excellent	-
20	Selvi	10, F	Aneurysmal bone cyst	Humerus (Rt)	Diaphysis	5 cm	Screws	-	-	-	-	-	5	14	Consolidated	Excellent	-